Deriving Data Inputs for the Wildland Fire Dynamics Simulator (WFDS)
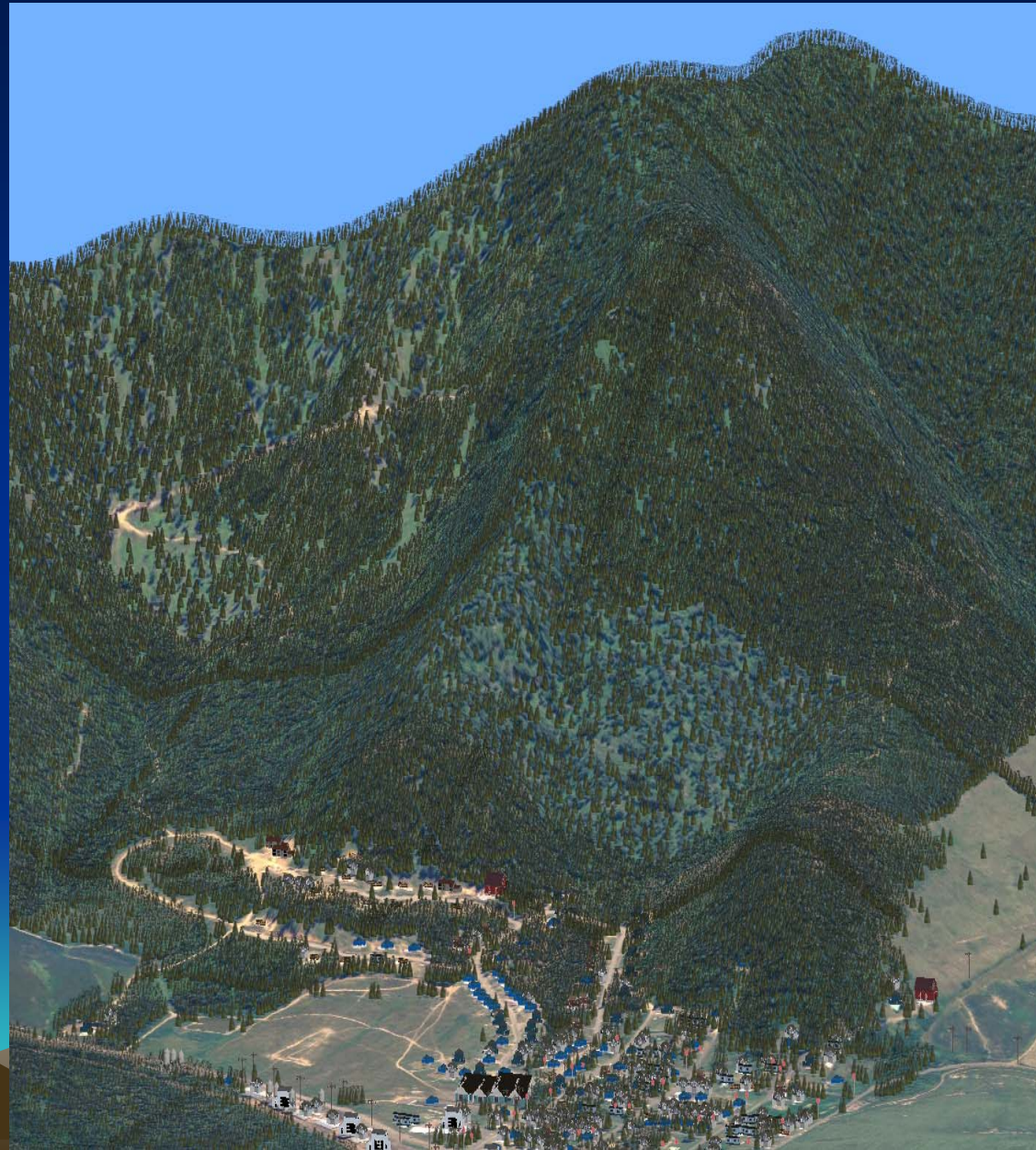
Derek McNamara

GIS Analyst

Coeur d'Alene Tribe

NIST Annual Fire Conference
April 4-5, 2007

Presentation Overview

- Purpose
- Data Sources
- Structure Extraction
    – Filtering
- Tree Extraction
   – Filtering
- GIS Linkage
- Future Work

Project Purpose

- Catastrophic Fires in WUI
  - ~9,000 homes destroyed 1985-1994 (NFPA)
- WUI Fire Behavior
- Few Physics-Based Models WUI Fires
- Cooperative Project
  - BFRL & CDA Tribe
    - CDA Tribe Provides Model Inputs
      - Structure Information
      - Tree Stem Locations (Crown Width, Height, Height to Live Crown, Bulk Crown Density)
      - Other Vegetation
      - Fire Barriers

Coeur d'Alene Tribe Reservation
Study Area Boundary

Coeur d'Alene Tribe Reservation
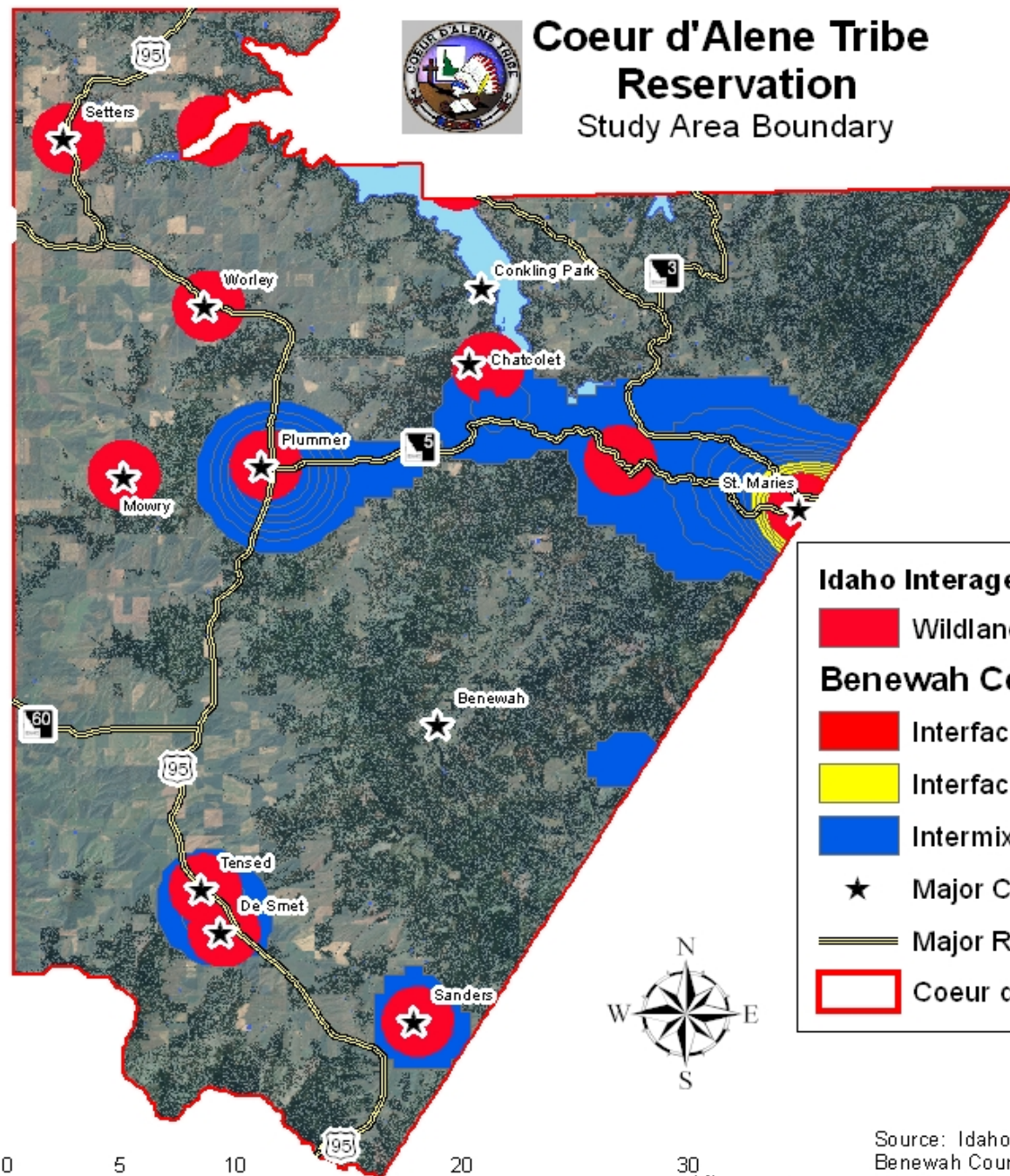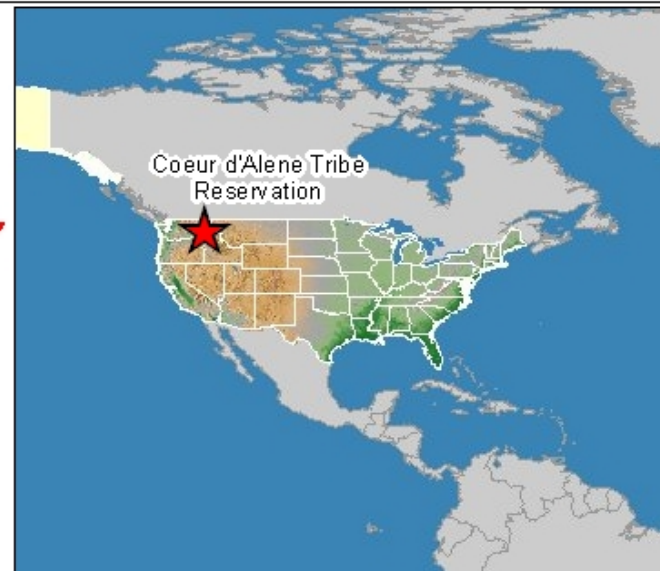
Idaho Interagency Assessment of Wildland Fire Risks

- Wildland Urban Interface

Benewah County Wildland Urban Interface

- Interface: High Density
- Interface: Medium Density
- Intermix: Low Density
- ★ Major Cities
- Major Roads
- Coeur d'Alene Tribe Reservation

Labels on map: Setters, Worley, Chatcolet, Plummer, Mowry, Conkling Park, St. Maries, Benewah, Tensed, De Smet, Sanders
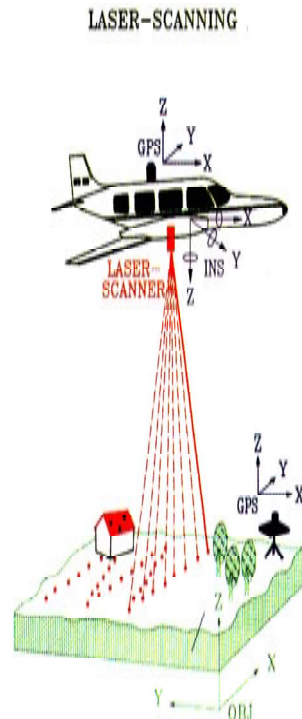
Scale: 0 5 10 20 30 Kilometers

Light Detection and Ranging (LiDAR)

What is LIDAR?

-Remotely Sensed Elevation Data

Why Would You Want LIDAR?
-High Accuracy (15cm ~ 6in)
-High Spatial Resolution (1-2m)
-Can be Collected in Vegetated Areas
-Cost Effective

LASER–SCANNING

Multiple Return
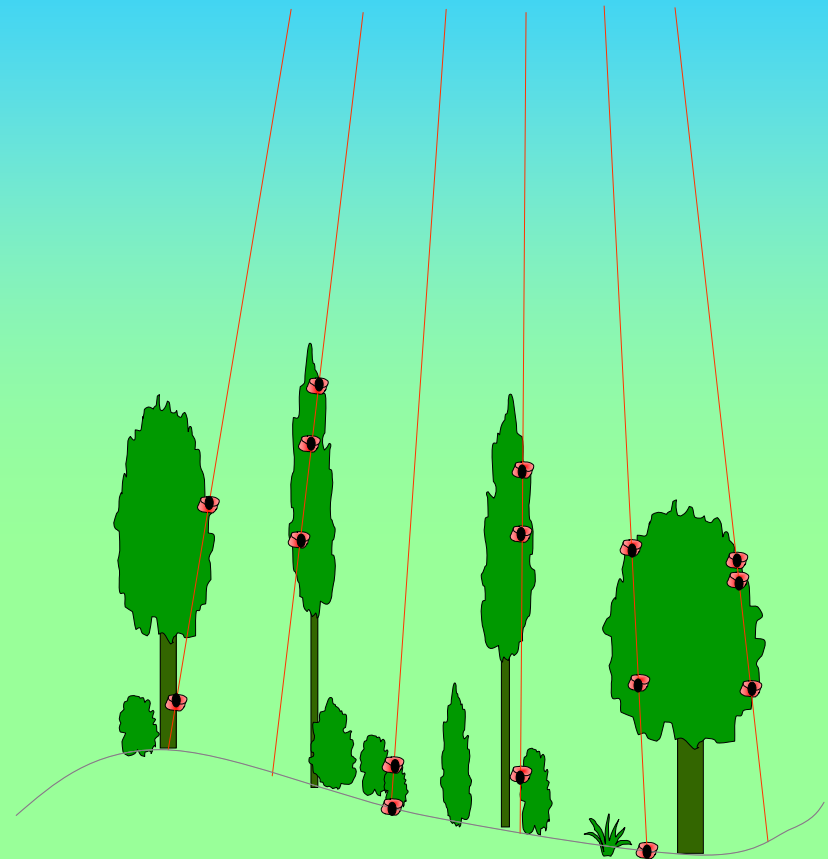
Structure Footprint Extraction Goals & Objectives

1) Extract Footprints WFDS Testing

- Entire CDA Tribe Reservation

- Database 11,000 Footprints
    - Building Materials
    - Height Statistics

2) Compare Methodologies

- Feasibility

- Identify/Develop Robust Methodology

Structure Footprint Extraction

- 4 Methods Examined[1,2]
  - Modified
- 2 LiDAR Height Data Height Directly
  - Derivative of Height (Texture)
- 2 Objected Oriented Image Classification
  - LiDAR Intensity Data
  - Multispectral Data
- Height and Area Thresholds
- Normalized Digital Surface Model
- Squaring Algorithm
  - Feature Analyst

1. Hewett (2005); Mass (1999); Rottensteiner & Briese (2005); Ibrahim (2005).

2. Details of methods: http://gis.cdatribe-nsn.gov/projects/lidarbuilding.aspx

Accuracy Assessment Methodology as described by Song & Haithcoat (2005)
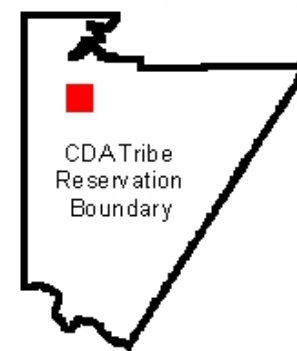
Building Extraction Comparisons Study Area
Worley, ID

Study Area (2.5KM X 2.5KM)
Building Footprints (426)

N

Area of Detail

CDA Tribe Reservation Boundary

0   0.15   0.3   0.6   0.9   1.2   Kilometers

Accuracy Assessment Completeness Measures

METHOD MEASURE	Texture Extraction	Height Extraction	Multispectral Extraction	LiDAR Intensity Extraction
Detection Rate (%)	69.7	73.5	72.3	66.7
Correctness (%)	16.9	19.0	28.0	12.4
Average Matched Overlay (%)	80.6	83.6	79.0	79.5
Average Area Omission Error (%)	19.5	16.4	21.0	20.1
Average Area Commission Error (%)	19.2	19.3	11.3	13.1

Accuracy Assessment Methodology as described by Song & Haithcoat (2005)

Accuracy Assessment Geometric Accuracy

METHOD MEASURE	Texture Extraction	Height Extraction	Multispectral Extraction	LiDAR Intensity Extraction
Average Root Mean Square Error (m)	2.02	1.90	2.03	2.40
Average Corner Difference (#)	1.4	1.59	1.51	2.01

RMSE

$$\frac{\sum\left(\sqrt{\dfrac{\sum(\text{d\textasciicircum2})}{\text{\# corners correct building}}}\right)}{\text{total number correct buildings}}$$

Corner Difference

$$\frac{\sum\left(\left|\sum(\text{detected building corners}) - \sum(\text{reference building corners})\right|\right)}{\text{total number correct buildings}}$$

Accuracy Assessment Shape Similarity

METHOD MEASURE	Texture Extraction	Height Extraction	Multispectral Extraction	LiDAR Intensity
Average Area Difference (%)	19.7	22.0	19.4	20.1
Average Perimeter Difference (%)	11.1	14.2	12.6	13.0

Perimeter Difference

$$\sum \left(\frac{|\text{detected building perimeter - reference building perimeter}|}{\text{reference building perimeter}} \right)$$
$$\overline{\text{total number of correct buildings}}$$

Area Difference

$$\sum \left(\frac{|\text{detected building area - reference building area}|}{\text{reference building area}} \right)$$
$$\overline{\text{total number of correct buildings}}$$

Initial Building Filter

P
U
L
S
E

G
R
O
U
P
I
N
G

First Return

Middle Return

First Return Height

First Return Minus Height

Last Return Height **Minus** Interpolated Ground Surface
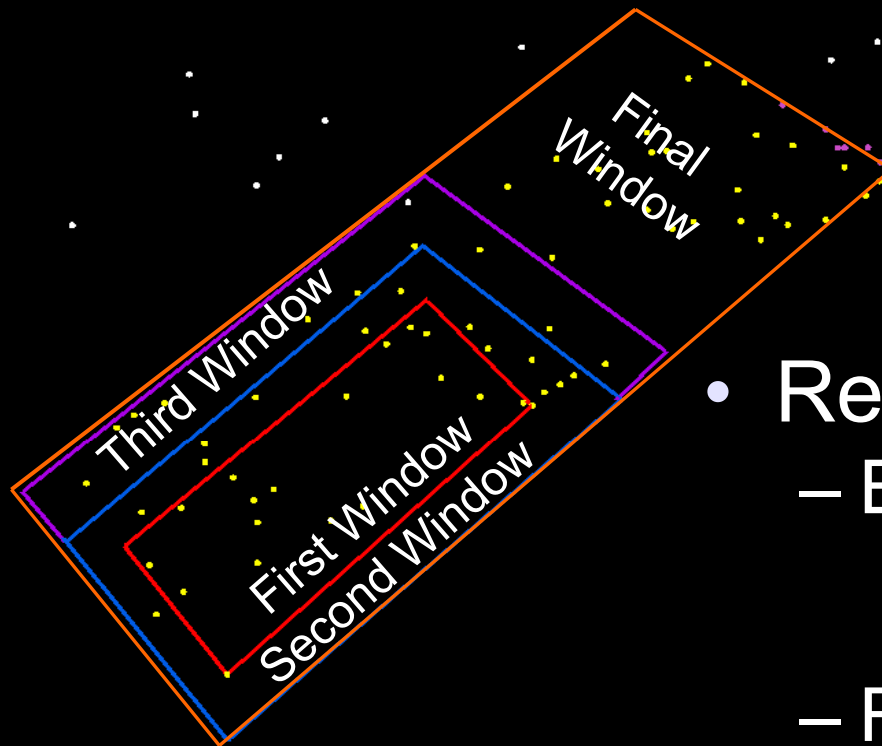
Last Return

- AboveThreshold Canopy Returns
  - Returns = NonBuilding
    - Except Last Return
  Ground Returns
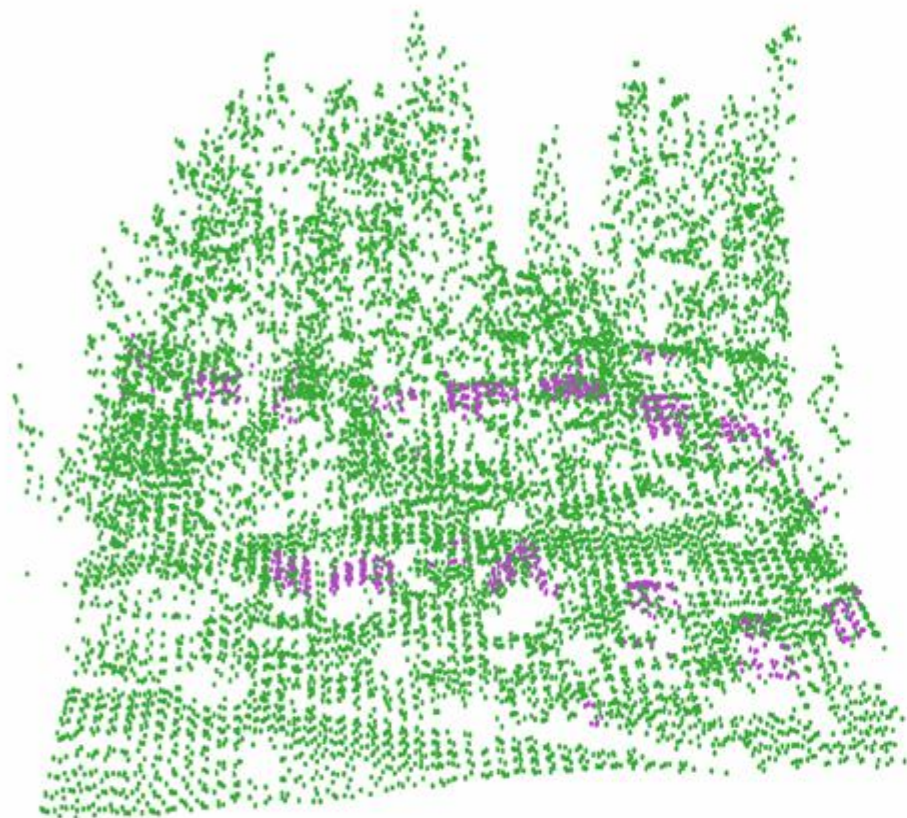- Reduces Points

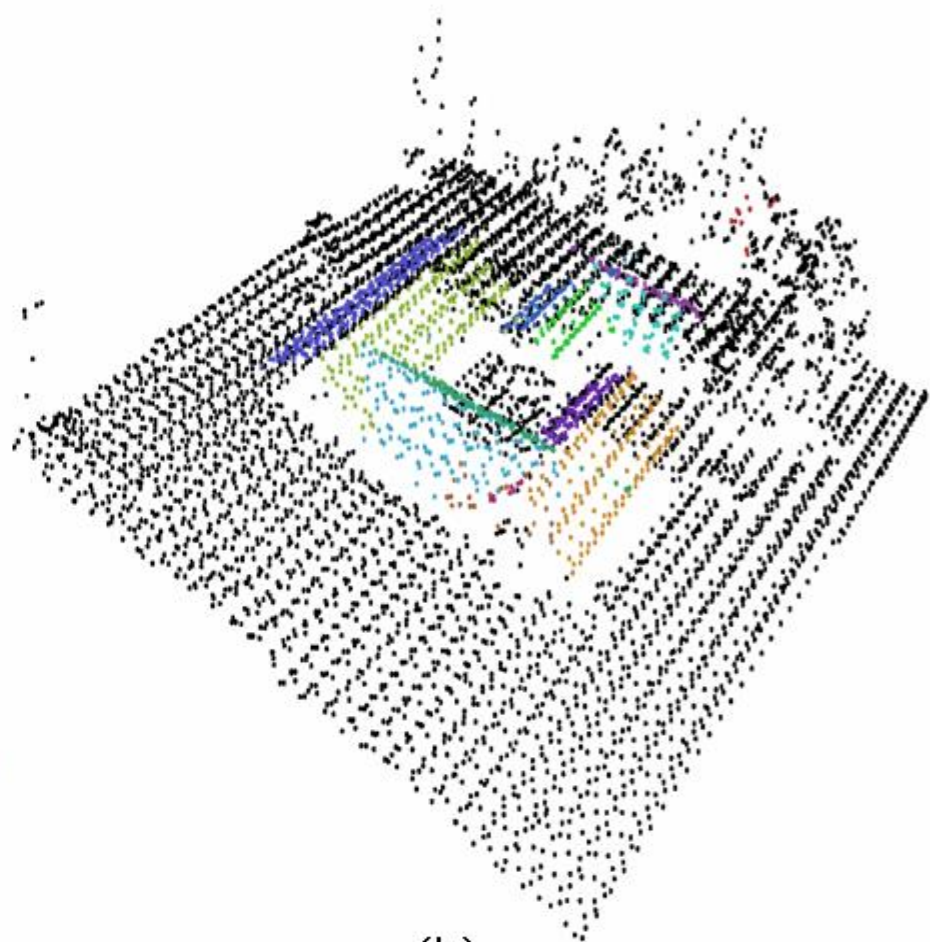Building Returns

Plane Fitting Filter

Final Window

Third Window

First Window

Second Window

- Region Growing
  - Expand Window
    - Direction Added Points
  - Repeat Process
    - No New Points
  - Move to Next Point
   - Repeat Process

(a)

(b)

Tree Stem Location Extraction

- 2 Methodologies Examined
  - LAS Processor (National Center for Landscape Fire Analysis (Eric Rowell))
    - Point Data Directly
    - Conifer Species
    - Modified By CDA Tribe
  - TreeVaw (Sorin C. Popescu (2004))
    - Interpolated Point Data
      - Surface Height Model
    - Adjust Crown Width & Height Relationship
  - Forested Environments

Tree Extraction Accuracy Assessments

- Small Park (~1/10KM)
- Even Aged Tree Stand
  - 60 Trees
    - 3 Deciduous
    - 57 Conifers
  - 15 Pole Features
    - 6 Telephone Poles
    - 4 Basketball Hoops
    - 4 Light Poles
    - 1 Totem Pole
  - 4 Shrubs
  - 2 Small Structures
  - 4 Playground Equipment
  - Metal Fence
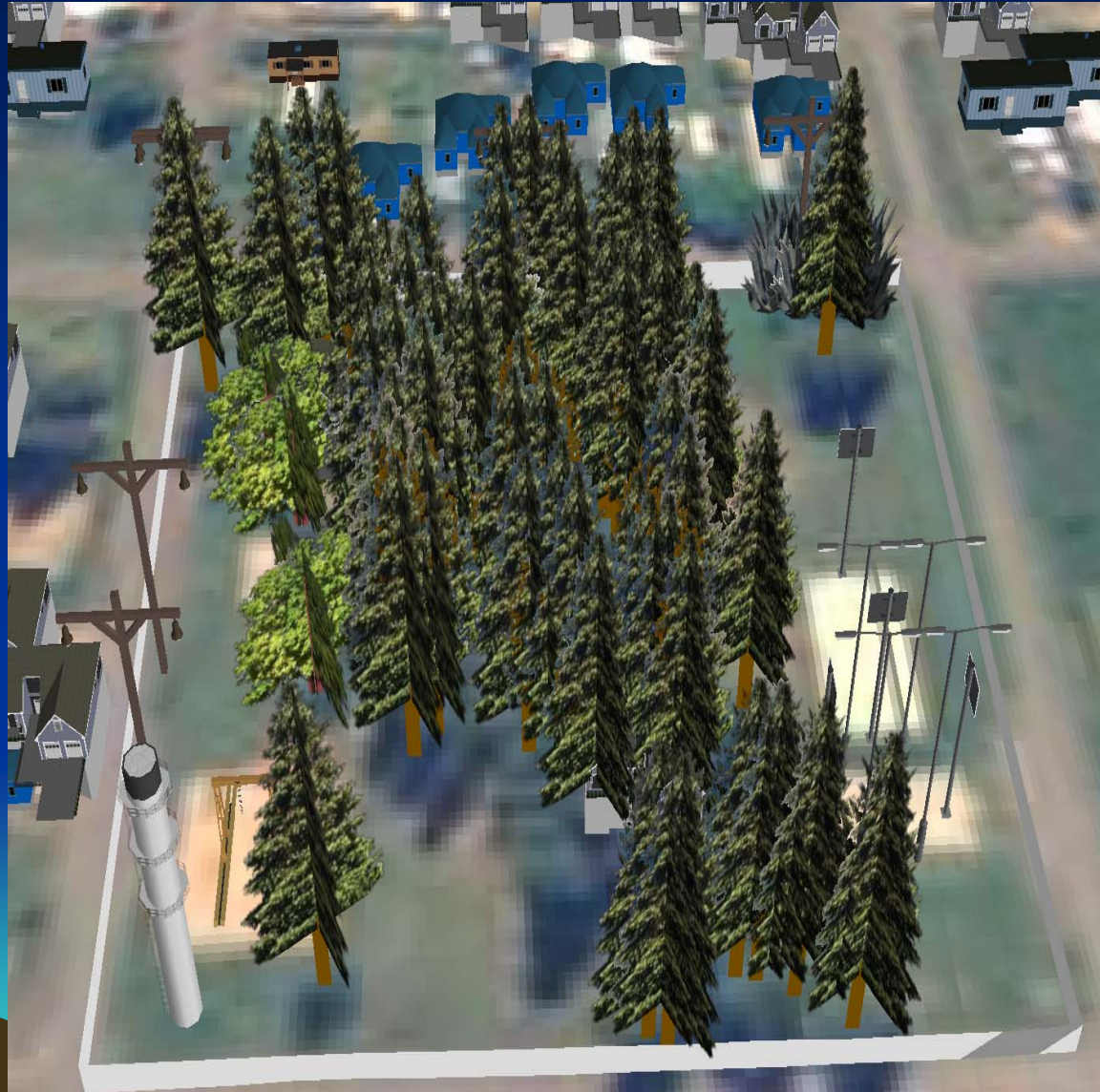
Preliminary Results TreeVaw

| Method	Field Survey	Tree Vaw
Number of Trees	60	77
Coniferous	57	~55
Deciduous	3	2
Pole Features	14	7
Shrubs	4	2
Playground Equipment	4	2
Canopy	N/A	~9

- Identify ~ 96% Conifer
- Identify ~ 66% Deciduous
- ~29% of Features Misidentified

- 2 Points Telephone Poles
- Highest Point Tree
- Modify LAS Processor

Other Data Inputs

- Shrubs
  - Canopy Cover & Height & Multispectral

- Height to Live Crown
  - Tree Height & Height to Live Crown

- Crown Bulk Density

- Fire Barriers (Roads & Dirt Patches)

Relationship Between Tree Height & Height to Live Crown

$y = 0.612x - 2.74$

$R^2 = 0.593$

Height to Live Crown (meters)

Tree Height (meters)
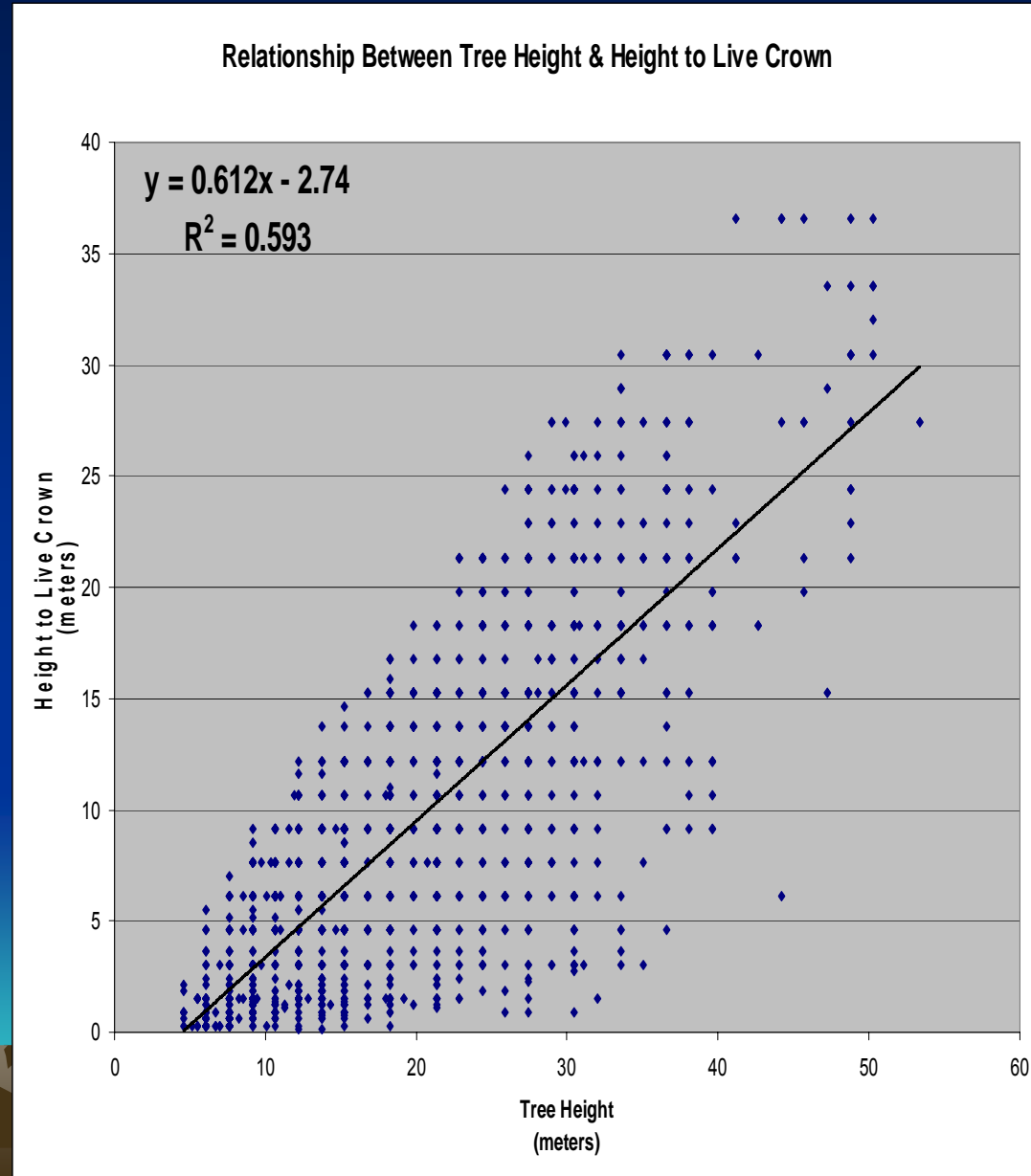
GIS Linkage
(Input File Creator)

- Selected Locations
- 2GB Limit
- Can Not Write Output Information

Preliminary Conclusions

- Building Extraction
  - Feasible
  - Remove Noise
- Tree Extraction
  - Feasible
    - Open, Even-Aged Stand
  - WUI Environment (?)
  - Uneven aged stand (?)
  - Smaller Trees (?)

Future Work

- Point Filtering Algorithms
  - Refinement
  - Increase Speed
- Crown Bulk Density & Height to Live Crown
- Ground Surveys
- Complete GIS Linkage

Acknowledgements

- Eric Rowell
  - National Center for Landscape Fire Analysis
- NIST/BFRL
- CDA Tribe
  - Jeremy Adams, Noel Sanyal, Heather Fuller, James Twoteeth, Bernie Jackson, Perry Kitt

Literature Cited

- Anderson, H.E., S.E., Reutebuch, and R.J. McGaughey. Forest measurement and monitoring using high-resolution airborne LIDAR. Oregon State University American Society of Photogrammetry and Remote Sensing (ASPRS) Student Chapter meeting, June 2, 2006, Corvallis, OR.

- Sulaga Ibrahim. Feature Extraction and 3D City Modeling Using Airborne LIDAR and High-Resolution Digital Orthophotos. GIS Master Thesis. University of Texas at Dallas. 2005.

- Haithcoat, T., and W. Song, J. Hipple. Automated Building Extraction and Reconstruction from LIDAR Data. R&D Program for NASA/ICREST Studies Project Report. September, 2001.

- Hewett, M. Automating Feature Extraction with the ArcGIS Spatial Analyst Extension. 2005 ESRI International User Conference Proceedings.

- Mass, G-H. The Potential of Height Texture Measures for the Segmentation of Airborne Laserscanner Data. Presented at the 4th *Airborne Remote Sensing Conference and Exhibition,* Ottawa, Ontario, Canada, 21-24 June 1999.

- Popescu, P.C, and A.U. Kini. TREEVAW: A Versatile Tool for Analyzing Forest Canopy LIDAR DATA – A Preview with an Eye Towards Future. Presented at the *ASPRS Images to Decision: Remote Sensing Foundation for GIS Applications,* Kansas City, Missouri, 12-16 September 2004.

- Rottensteiner, F. and C. Briese. A New Method for Building Extraction in Urban Areas from High-Resolution LIDAR Data. IAPRSIS, Vol. XXXIV/3A, 2002, Graz, Austria, pp. 310-317

- Song, W., and T.L. Haithcoat. Development of Comprehensive Accuracy Assessment Indexes for Building Footprint Extraction. Geoscience and Remote Sensing, IEEE Transactions on. 43:2. February, 2005.